PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U.S.DEPARTMENT OF AGRICULTURE
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NATURAL DURABILITY OF SOME WOODS USED IN HAWAII. . . results of 9½ years' exposure

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USDA Forest Service
Research Note PSW-292
1974

Skolmen, Roger G.
1974. **Natural durability of some woods used in Hawaii . . . results of 9½ years' exposure.** USDA Forest Serv. Res. Note PSW-292. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 6 p., illus.

Eight Hawaii-grown and seven imported wood species are being evaluated for their natural resistance to decay and insect attacks. The test, at the Makiki Exposure Site in Honolulu, consists of 2- by 4-inch stakes of each species set in the ground, and unpainted post-rail units placed above the ground. After 9½ years, the stake test has been completed and the post-rail unit test has provided conclusive findings. Redwood was most durable in both tests, followed by three Hawaii-grown eucalypts. Tropical ash and white oak were low in durability in both tests. There were differences in rating order for in-the-ground and above-ground durability for the other species.

Oxford: 814.1: 844.2: 835.3: (969).
Retrieval Terms: wood durability; wood decay; wood destroying fungi; termites; Hawaii.

Since 1963, several wood species commonly used in Hawaii have been undergoing exposure tests for natural durability in Honolulu. Of the 15 species being tested, eight are local, and the others, imported. Purpose of the tests is to compare the resistance of untreated heartwood in each species to decay and insect attacks. In one test, stakes—each 2 by 4 by 18 inches— were set to half their length in the ground *(fig. 1)*. In the other test, post-rail units were placed above the ground *(fig. 2)*.

The stakes were removed for inspection and set back in place twice each year. Inspections of the post-rail units requires destructive observations. The first two inspections of the post-rail units covered three units of each species. They were made 1½ and 4 years after the test was started. The latest inspection was of five units of each species. Four units were left for a future final inspection.

Preliminary results, reported in 1968, showed that redwood was far more resistant to both decay and insects than any other species in the stake test.[1] In the post-rail unit test, tropical ash was the least resistant species to decay and insects.

After 9½ years, the stake, or "graveyard," test has been completed. And the post-rail unit test has provided conclusive information about the relative durability of the test species. The results are similar to those reported earlier: redwood ranks first in resistance, and tropical ash has proved to be least resistant to decay and insect attacks.

EXPOSURE SITE

Tests are at Makiki Exposure Site in Honolulu. The environment there for wood decay organisms and wood-destroying insects is similar to that found in many of the more humid residential areas on Oahu,

Figure 1—Top, Stakes as they appeared in 1963, when they were installed at the Makiki Exposure Site, Honolulu, Hawaii, and **Bottom,** as they were 9½ years later.

Figure 2—Post-rail units show results of 9½ years exposure at the Makiki Exposure Site, Honolulu, Hawaii.

i.e., Moanalua, Kalihi, Nuuanu, Pauoa, Manoa, and Palolo Valleys, as well as similar areas on the windward side of the island, such as Haiku and Maunawili. Some locations on other islands in Hawaii and elsewhere have similar conditions. The rainfall is about 65 inches per year, with a mean daily temperature in the 70's throughout the year.

Subterranean termites *(Coptotermes formosanus)* are present at the site, but may be somewhat inhibited by occasional water logging of the soil during extended wet periods. Damage by wood boring insects other than termites is common in the area. Damage by the dry-wood termite *(Coptotermes brevis)* has been found in the post-rail units, but is not common.

DURABILITY IN THE GROUND

Fourteen species of wood were compared in the stake test *(table 1)*. Six of the 14 were species that are imported to Hawaii in lumber form and used there extensively; the others were locally grown woods.

All samples were representative of wood that was available in the local market in 1963. The imported wood samples were cut from 10 or more boards of each species selected from separated parts of lumber piles in several lumber yards. Samples of redwood, western redcedar, and Douglas-fir included a range of annual ring-widths and density.

Redwood was the most durable and tropical ash the least durable of the 14 species tested *(table 1)*. Next best to redwood were the red-colored Hawaii-grown eucalypts—robusta and saligna. Blackbutt was the only species in the test for which no stakes were removed because of insect damage, but its stakes did not last as long as those of robusta and saligna. Insect damage was primarily by subterranean termites and was low in blackbutt, redwood, saligna, "Philippine mahogany," meranti, and Australian toon. Insect damage was rather serious in the rest of the species.

Douglas-fir was less durable than the eucalypts, closely followed in order of decreasing durability by "Philippine mahogany" and western redcedar. Western redcedar is usually classed with redwood as a highly resistant wood, but in this test it proved to be quite inferior to Douglas-fir—usually classed as only moderately resistant. Western redcedar and Douglas-fir had more subterranean termite damage than "Philippine mahogany" and meranti.

In terms of service life, meranti and the six species below it (see *table 1*) are less than half as durable as redwood. The presence of sapwood in some of the white oak probably accounts for its low resistance to both decay and insects. Sapwood damage was ignored during inspections, but its presence probably speeded the rate of heartwood infection. White oak should probably be considered similar to ohia in resistance to decay and insects. Ohia is generally considered to be a durable wood in Hawaii, but this test showed it to be only moderately resistant to decay and insects. Australian toon showed some insect resistance, but was quite low in decay resistance. Tropical ash was well below the others in durability.

Counts of annual rings-per-inch of cross-section were made on samples of redwood, western redcedar, and Douglas-fir. I found no clear relationship between time of failure and rings per inch. Early failures occurred in redwood stakes with from 7 to 14 rings per inch. Late failures occurred in stakes with 6, 10, and 34 rings per inch. The other two species yielded simi-

Table 1—*Condition of 2- by 4-inch heartwood stakes after 9½ years' exposure in the ground, Makiki Exposure Site, Honolulu, Hawaii*

Species	Stakes in test	Removed due to[1]		Average life
		Decay	Decay and insects	
		— *Percent* —		*Years*
Redwood *(Sequoia sempervirens)*	24	54	8	[2]9.4
Robusta[3] *(Eucalyptus robusta)*	25	64	12	[2]7.9
Saligna[3] *(Eucalyptus saligna)*	25	84	8	[2]7.3
Blackbutt[3] *(Eucalyptus pilularis)*	22	82	0	[2]6.5
Douglas-fir *(Pseudotsuga menziesii)*	25	60	32	[2]6.3
"Philippine mahogany"[4] (various spp.)	24	83	8	[2]5.9
Western redcedar *(Thuja plicata)*	23	57	43	4.8
"Meranti"[5] (*Shorea* spp.)	22	91	9	4.2
Silk-oak[3] *(Grevillea robusta)*	24	83	17	4.0
Ohia[3] *(Metrosideros collina)*	24	75	25	3.8
Australian toon[3] *(Toona australis)*	24	92	8	3.8
Koa[3] *(Acacia koa)*	24	71	29	3.5
White oak (*Quercus* spp.)	24	50	50	3.0
Tropical ash[3] *(Fraxinus uhdei)*	25	64	36	1.9

[1] A stake is removed when 50 percent or more of its cross-section has been destroyed by the indicated agent or agents.

[2] Average life estimated as all stakes had not failed.

[3] Wood was grown in Hawaii.

[4] "Philippine mahogany" lumber was obtained from a local lumber dealer as "dark red Philippine mahogany." The U.S. Forest Products Laboratory, Madison, Wisconsin, determined it to be a mixture of *Shorea polysperma* (tangile), *Shorea almon* (almon), and *Tarrietia javanica* (lumbayau). The latter is not a "Philippine mahogany." Taken together the mixture may be considered representative of wood sold in Hawaii as dark red Philippine mahogany by yards dealing with mills in the Philippines.

[5] "Meranti" lumber was obtained from a different lumber dealer than the one who supplied the "Philippine mahogany," also as dark red Philippine mahogany. The U.S. Forest Products Laboratory identified it as a mixture of several *Shorea* spp., all from Malaya or Borneo. The wood is representative of that sold in Hawaii as "dark red Philippine mahogany" by yards dealing with mills in Japan.

lar results.

Observations of the type of decay present, white or brown, were made for each failed stake. Brown rots were predominant in all species except tropical ash, white oak, and blackbutt. Some stakes of every species failed from white rots.

A primary objective of this test was to determine how the durability of the local woods compared to well-known imported woods. The three eucalypts are clearly superior to the other local woods, but not equal to redwood in durability in ground contact. Robusta and saligna are more durable than Douglas-fir and "Philippine mahogany," while blackbutt is about equal to them. All the other local woods if used in ground contact are less durable than Douglas-fir and western redcedar.

DURABILITY ABOVE THE GROUND

The post-rail unit test includes the same species as the stake test and, in addition, western hemlock. Western hemlock was not included in the stake test because it is known to have poor decay resistance in ground contact.

The test originally included 15 units of each species, all untreated and unpainted. The post and rail pieces were end-matched by board. I inspected them externally twice a year. When sufficient deterioration was judged to have occurred, a randomly selected sample of units was removed for internal inspection.

Inspection consisted of sawing the post and rail down the center, dividing the sawn faces into tenths, and classifying each one-tenth section on a scale of 0 to 10 for severity of decay and insect damage. To rate each species, I added up the severity ratings for each section and averaged them for the replications inspected *(table 2)*. In addition, I recorded the remains of post-rail units present at inspection time that had been destroyed by decay and insects while in place on the exposure racks.

Decay was the principal cause of damage and failure in the post-rail units *(fig. 3)*. Insects had often contributed to the total damage, but were not the primary damaging agent in any of the units inspected at 9½ years. At the previous inspections, I had found galleries and pellets of dry-wood termites in some specimens. No damage that could be attributed to termites with certainty was found in the more recent inspection. Larvae of cerambycid insects were found in Australian toon and tropical ash samples. Most units except redwood had evidence of insect nibbling at the joint between the post and the rail.

As with the test of durability in the ground, red-

wood was the most durable above ground, and tropical ash the least. The eucalypts again ranked behind redwood, while Douglas-fir ranked much lower than in the stake test.

Variation in decay between units has been large, but results are reasonably conclusive. A general classification of above-ground decay and insect resistance based on the available data would be:

Very resistant:	Redwood
Resistant:	Blackbutt, saligna, robusta, "meranti," silk-oak, ohia, western redcedar
Moderately resistant:	Australian toon, koa, Douglas-fir, "Philippine mahogany"
Non-resistant:	White oak, western hemlock, tropical ash.

DISCUSSION

The results reported are for accelerated tests that were designed to promote the rate of decay and insect damage to wood. In normal use, the species tested would not be treated as harshly and, consequently, would give a much longer service life.

If the wood is exposed in use in a manner similar to that in these tests, results should be similar. One example of such use would be a wood fence; redwood would obviously be preferable—unless the alternative species was treated with preservatives. Another example of somewhat similar use could be roofing shingles or shakes. These are made of both western redcedar and redwood. The results indicate that redwood should last longer than western redcedar in the wetter parts of Hawaii.

Table 2—*Average ratings*[1] *of interior condition of post-rail units after 4 and 9½ years' exposure, Makiki Exposure Site, Honolulu, Hawaii*

Species	4 years' exposure				9½ years' exposure				
	Posts		Rails		Posts		Rails		Units[2] failed
	Decay	Insects	Decay	Insects	Decay	Insects	Decay	Insects	
									Percent
Redwood	0	0	0	0	0	0	0	0	–
Blackbutt[3]	0	0	1	0	0	0	1	0	–
Saligna[3]	0	0	0	0	1	0	1	0	–
Robusta[3]	0	0	0	0	1	0	1	1	–
"Meranti"	0	0	0	0	1	1	2	1	–
Silk-oak[3]	0	0	0	0	1	1	2	2	–
Ohia[3]	0	0	0	0	1	1	3	1	–
Western redcedar	0	0	0	0	1	1	3	1	–
Australian toon[3]	2	0	2	2	8	2	12	3	–
Koa[3]	3	3	6	6	9	3	24	2	–
Douglas-fir	31	10	2	0	20	0	21	0	33
"Philippine mahogany"	0	0	1	0	22	1	47	3	22
White oak[4]	7	8	33	34	10	2	48	2	44
Western hemlock *(Tsuga heterophylla)*	34	9	31	19	52	15	64	15	22
Tropical ash[3]	84	83	86	69	89	17	84	20	89

[1] Based on a scale of 0 = no deterioration to 10 = complete destruction, for decay and for insect damage by one-tenth parts of post and rail; summed for each post and rail; and averaged for all posts and rails examined. Rating may, therefore, be considered the percent of posts and rails destroyed by decay or by insects. It was seldom possible to accurately proportion decay and insect damage, so the ratings for both types together sometimes add to more than 100.

[2] Units that have fallen apart in place or were about to when observed.

[3] Wood grown in Hawaii.

[4] Some white oak units were partly sapwood; only heartwood was rated.

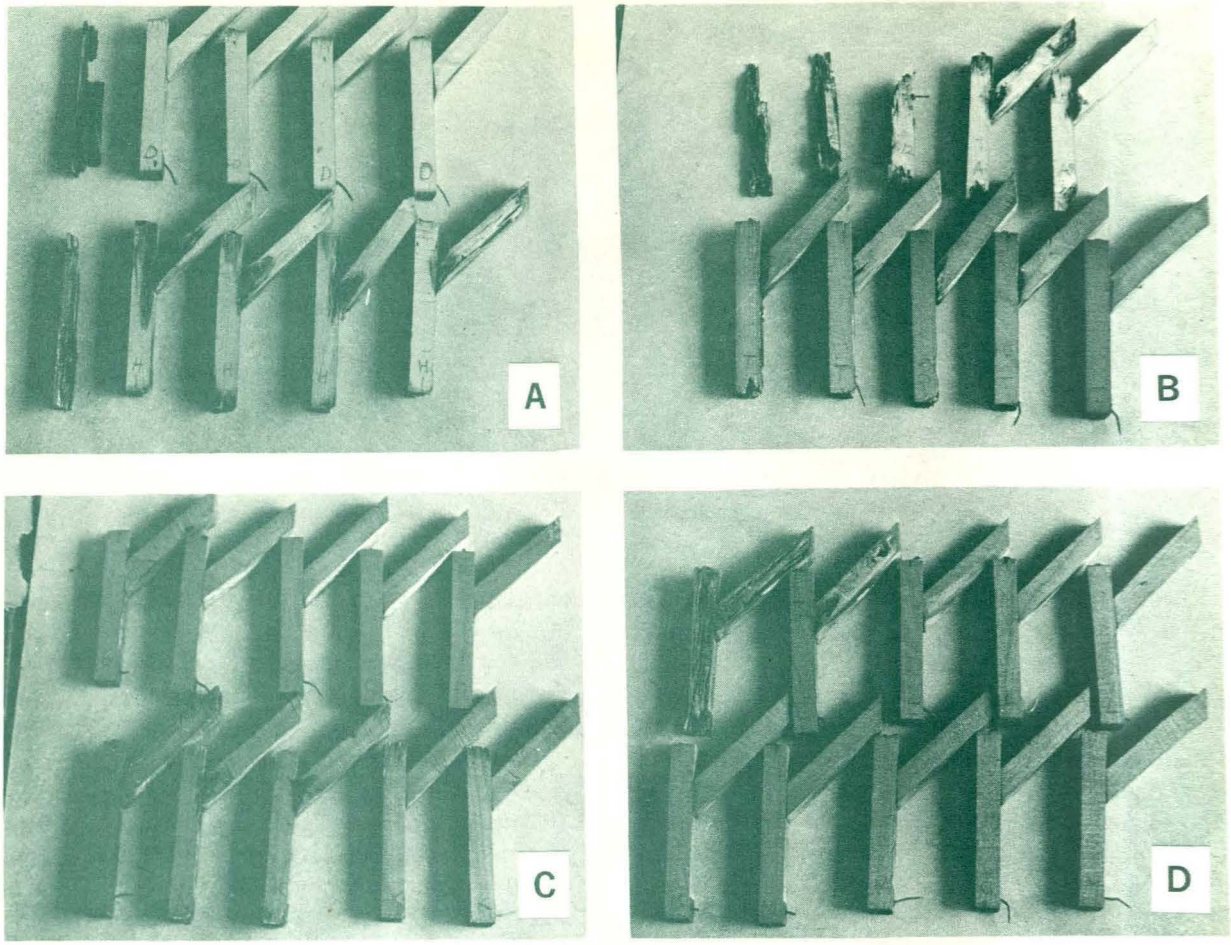

Figure 3—Interior of post-rail units:**A, Top,** Douglas-fir; **Bottom,** western hemlock, **B, Top,** tropical ash; **Bottom,** Australian toon, **C, Top,** ohia; **Bottom,** koa, **D, Top,** "Philippine mahogany"; **Bottom,** meranti.

NOTE

[1]Skolmen, R. G. *Natural durability of some woods used in Hawaii. . .preliminary findings.* USDA Forest Serv. Res. Note PSW-167. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif. 7 p., illus. 1968.

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U.S. Forest Service research in Hawaii
is conducted in cooperation with
Division of Forestry
Hawaii Department of Land and Natural Resources

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